Cryogenic Summary - Testing D2L102 in MAGCOOL

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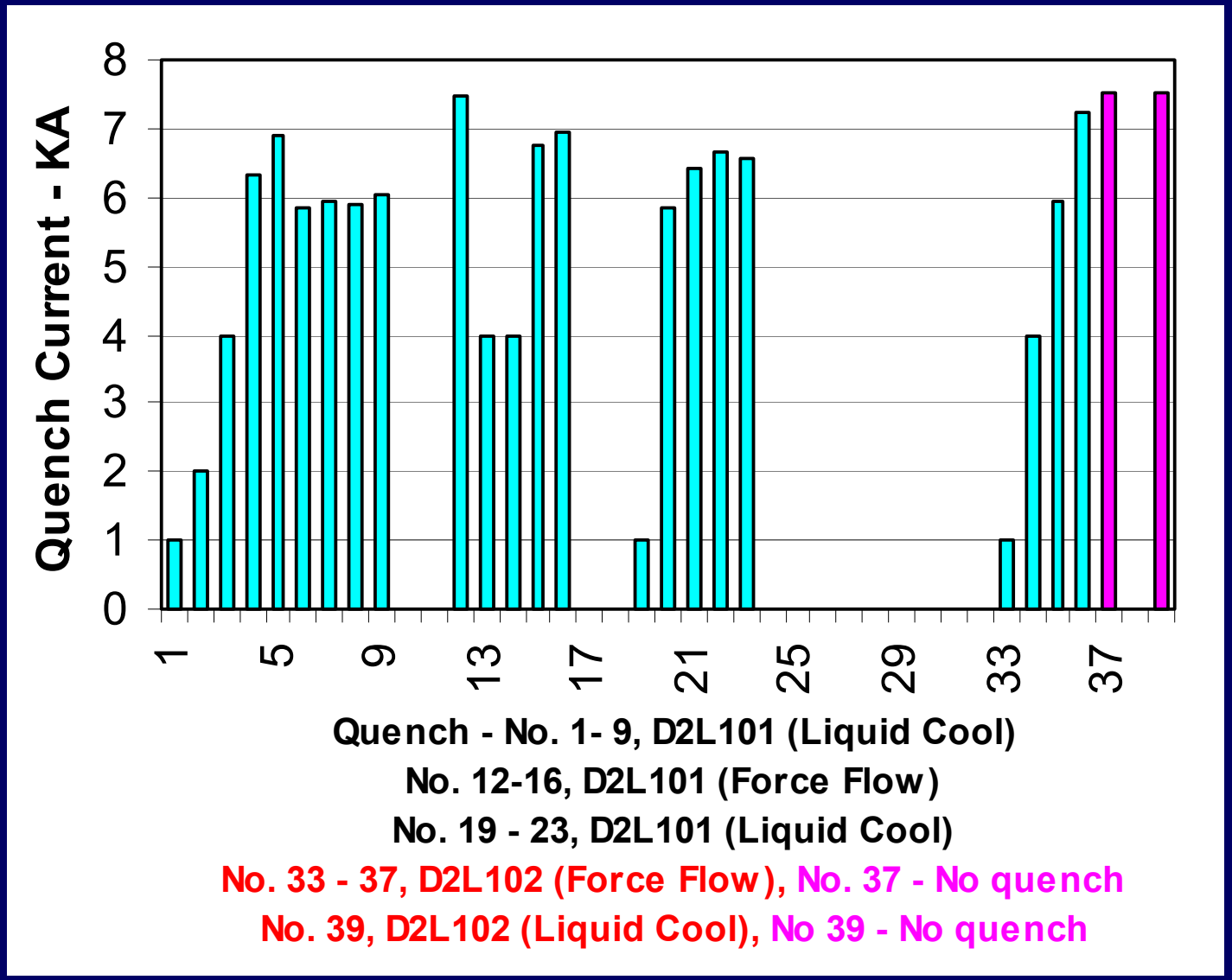
- Difference between D2L102 and D2L101
- Operating Summary
- Cooldown to 100 K and 6 K
- Test Condition – 12 atm, 4.50 K (forced flow)
- Test Condition – 1.43 atm, 4.65 K (liquid cool)
- Discussion and Summary

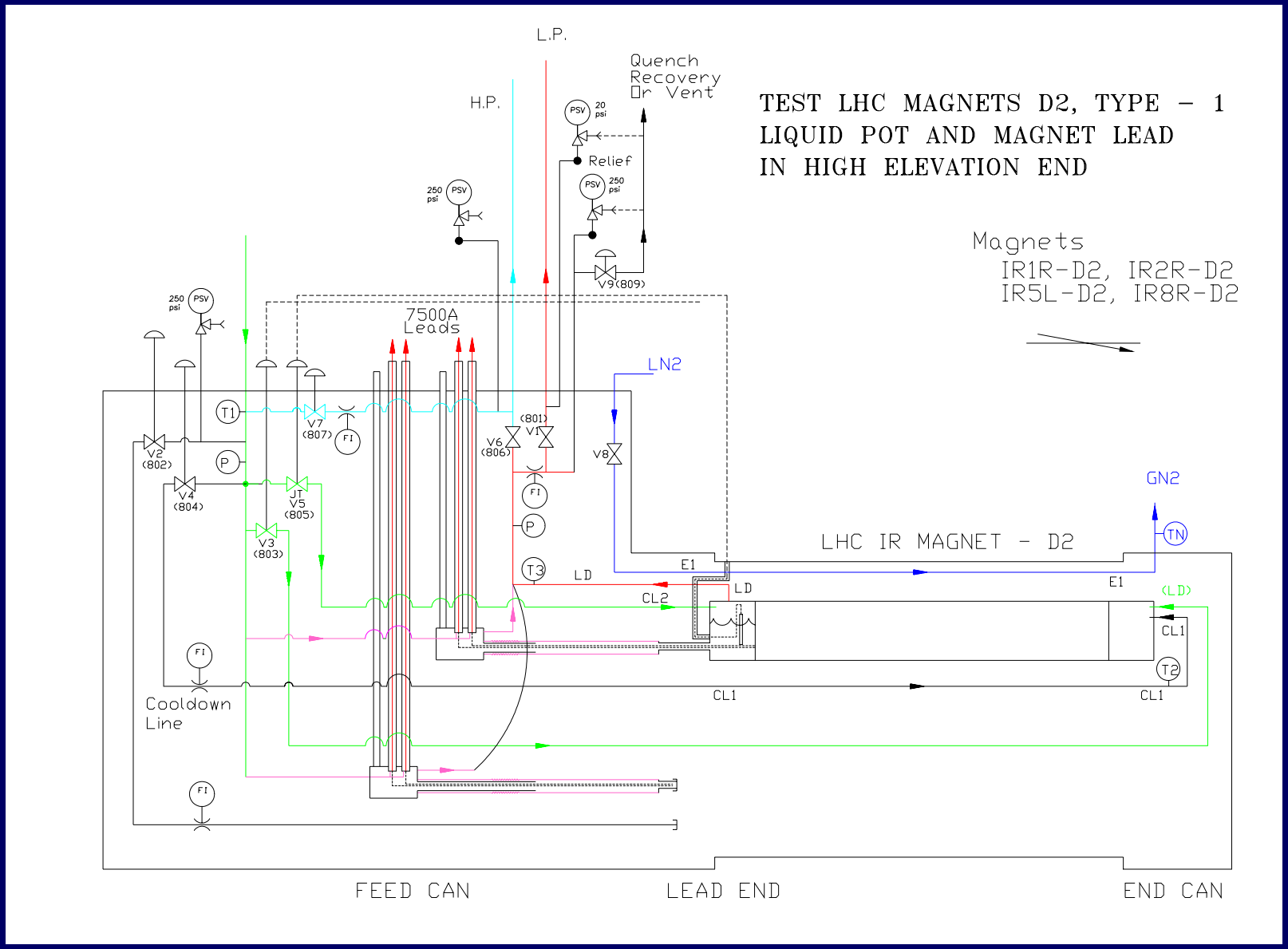
Difference between D2L102 and D2L101

- After two training quenches, D2L102 can be ramped to 7500 A without quench using either forced flow cooling (at ~ 4.50 K) or liquid helium cool (at ~ 4.65 K). The cryogenic test condition for D2L102 is basically the same as that for D2L101
- Following improvements on the Feed Can are made for D2L102
  - Reduce heat load to lead pots by connecting flow controller to two unused leads
  - Set up 1.23% slope for test bay
  - Install a jumper pipe to allow filling liquid helium from low elevation end (not used in this test)
  - Install superinsulation around the end of beam tubes and D2 end volume

Quench Current for D2L101 & D2L102



Flow diagram for D2L102 – Capable of Feeding LHe from either high or low elevation ends



Operating Summary

- 6/1-3 Cooldown - 300 to 100 K
- 6/3-4 Cooldown - 100 to 6 K
- 6/4 Reach 6 K
- 6/4 Test D2 via forced flow cooling
- 6/5-6 Switch to liquid cool
- 6/6-7 Test D2 in liquid helium

Test Conditions

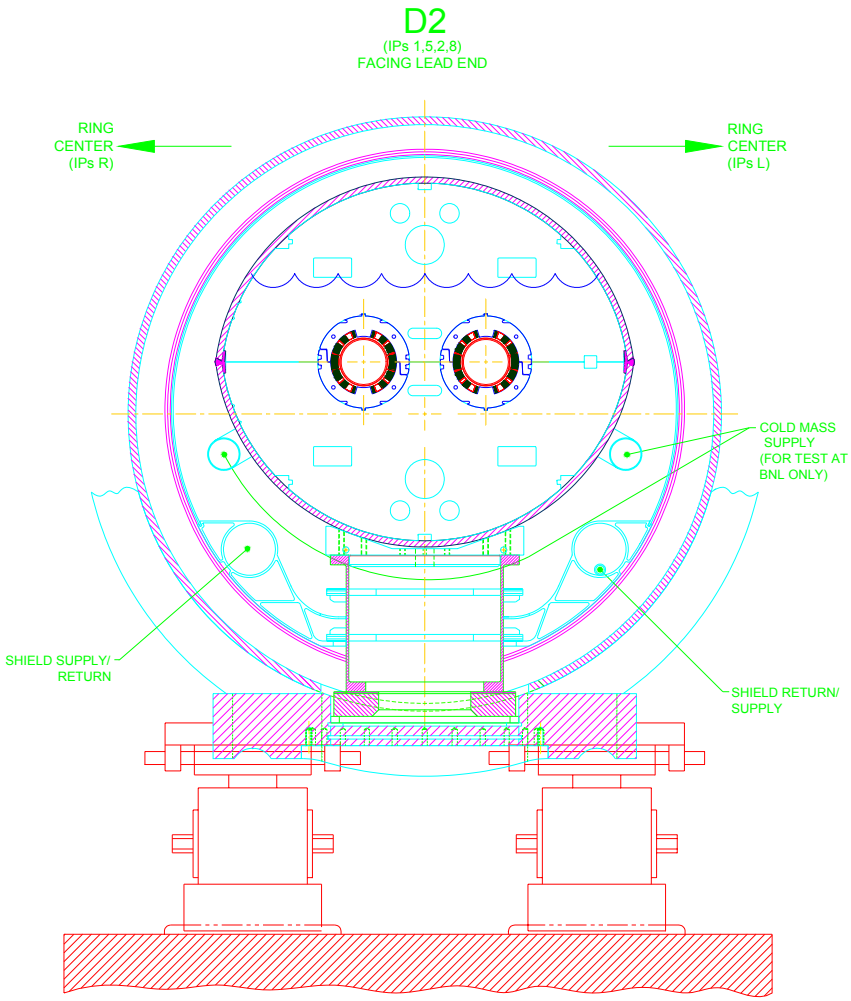
- Forced flow cooling
  12 atm, 4.50 K & 60 g/s

- Liquid helium cooling
  1.43 atm & ~ 4.65 K in D2,

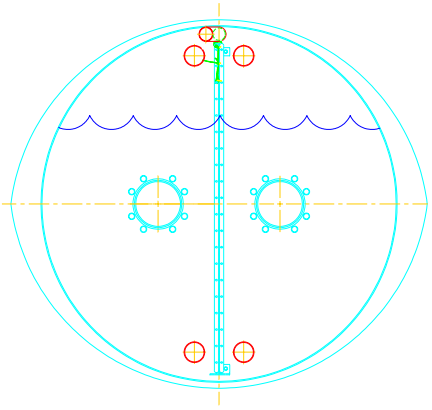
  Liquid level in end volume
    high elevation end: 75% (6 cm above coil)
    low elevation end: 95% (16 cm above coil)

  JT Valve
    Inlet condition: 12 atm & 4.0 K
    Liquid after expansion ~ 90 %

Sectional view of D2 with liquid level in high elevation end (left), Level gauge in end volume (right)



Level gauge in end volume of D2 cold mass

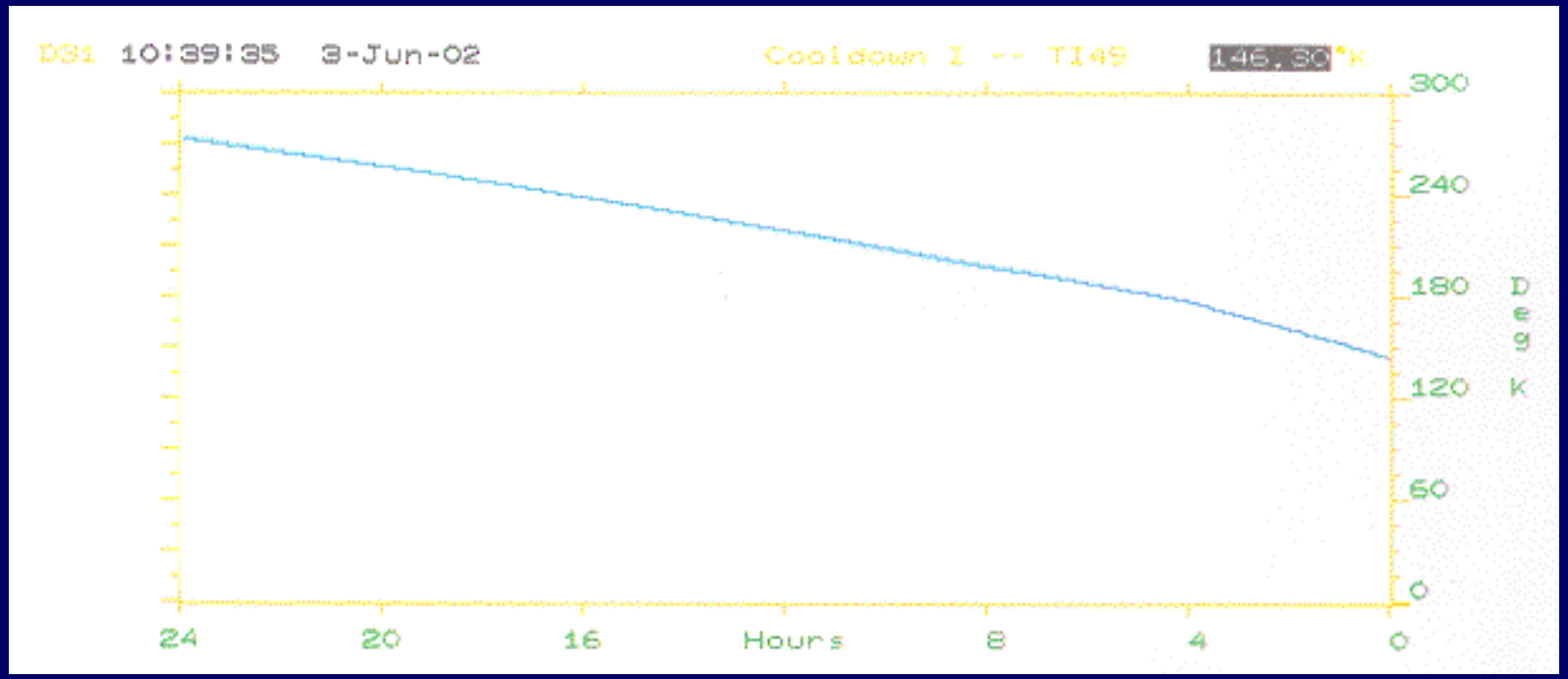


Shell of cold mass is used as liquid helium vessel with level gauge installed in the end volume for liquid control. Typically, liquid is kept at 75 % or ~6 cm above supderconducting coil

Tests Performed - D2L102

- 1st test group (forced flow cooling ~ 4.50 K),
  - Shut off - 1000 A (6/4)
  - Strip Heater - 4000 A (6/4)
  - 1st quench – 5944 A (6/4)
  - 2nd quench – 7213 A (6/5)
  - Ramp – 7500 A (6/5) (at 7500 A ~ 30 min.) (Strip Heater due to P. S. fault)
- 2nd test group (liquid cool ~ 4.65 K),
  - Ramping - 7500 A (6/6)
  - Strip Heater - 6600 A (6/7)
  - Ramp - 7500 A (6/7) (4 times)
  - Quench - 7500 A (6/7) (at 7500 A ~ 30 min.) (Strip Heater due to P. S. fault)

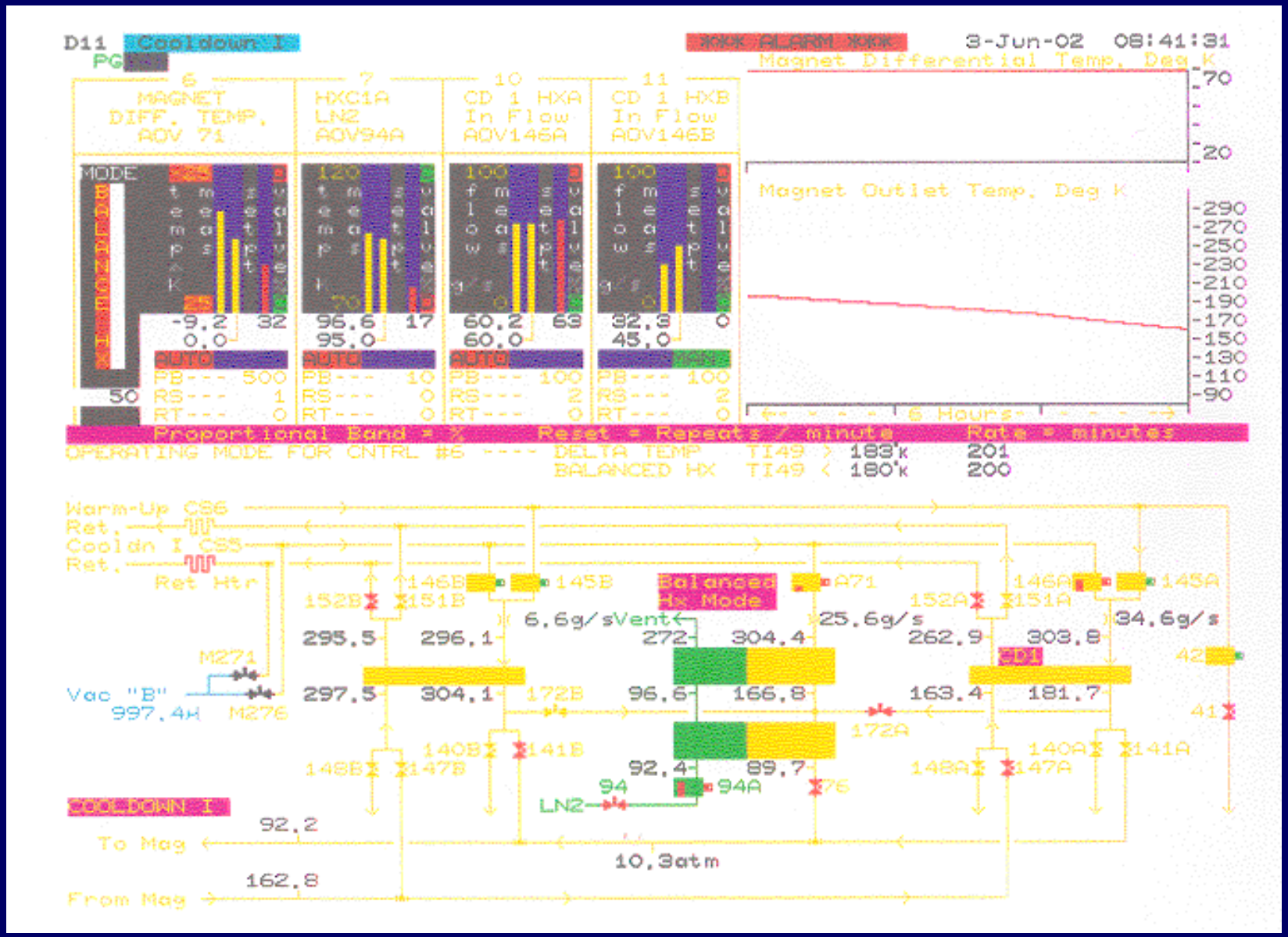
Cooldown from 300 – 100 K for D2L102



•100 K Cooldown time ~ 43 hours compared with ~ 54 hours for D2L101.

•Faster cooldown rate is achieved using 60 g/s of helium flow compared with 45 g/s previously used. Note 60 g/s is essentially the maximum flow for MAGCOOL cooldown I.

Operating Condition for 100 K Cooldown of D2L102

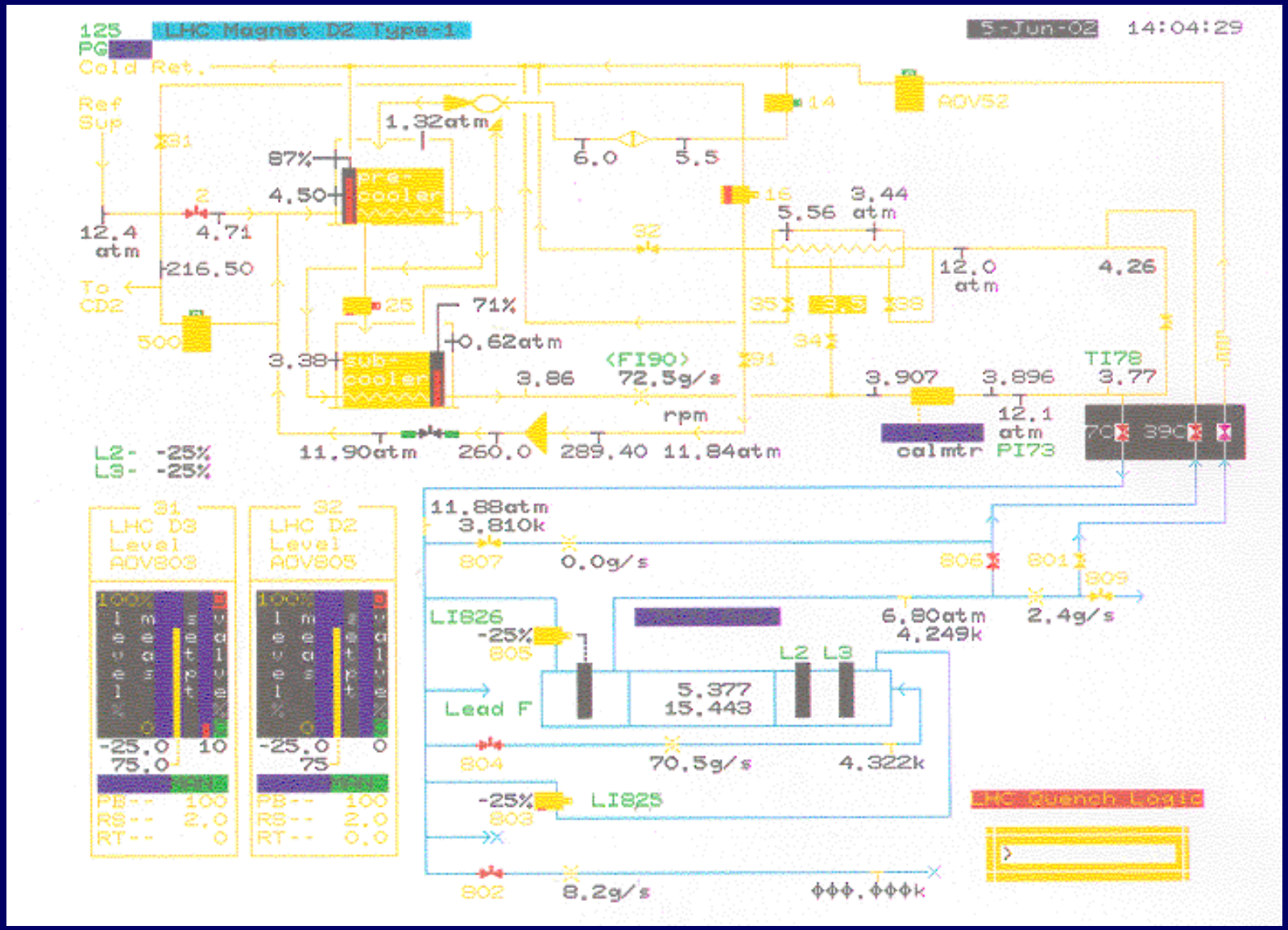


Cooldown from 100 – 6 K for D2L102

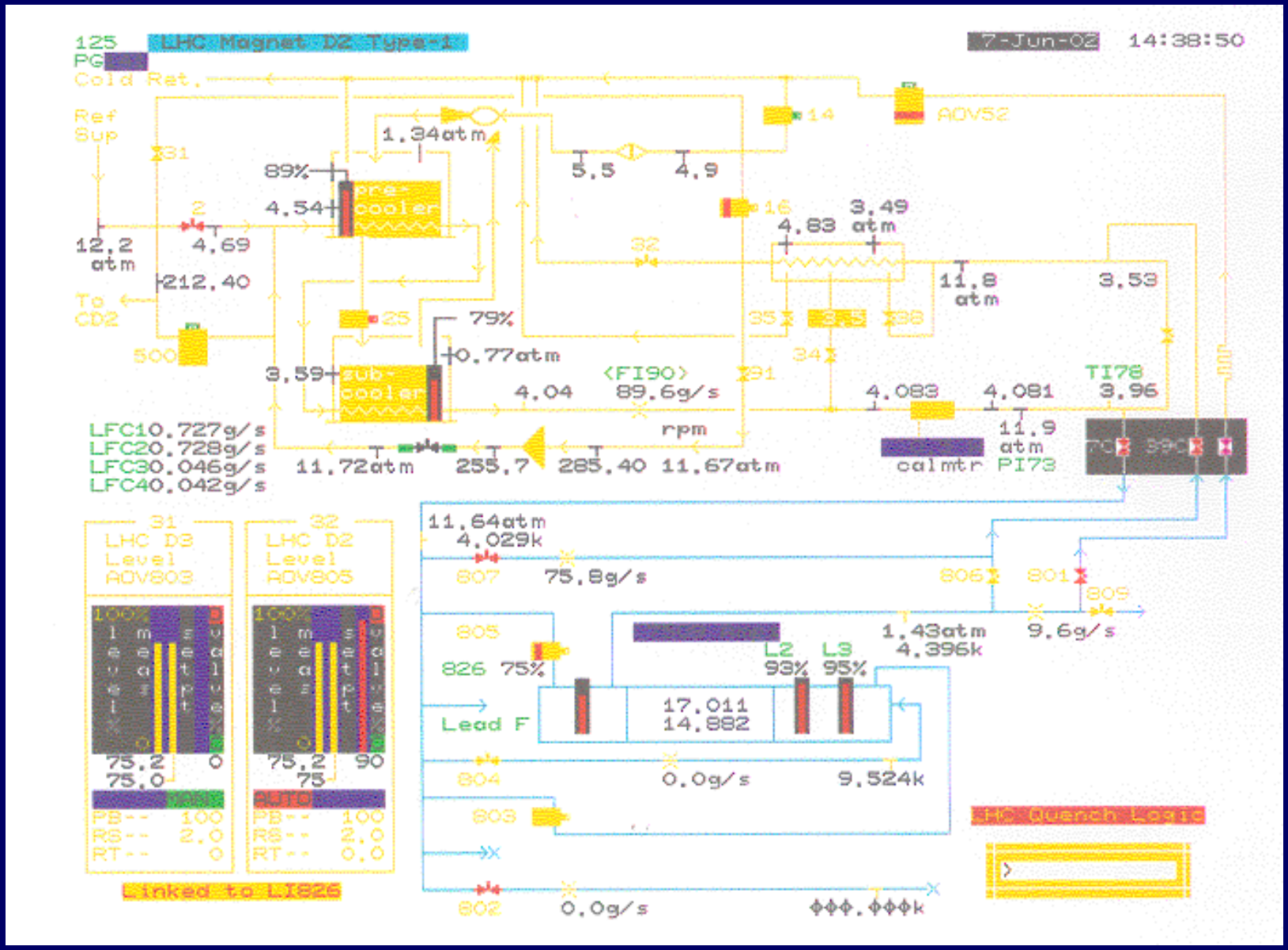
•Cooldown time (100 to 6 K) is ~ 17 hours compared with ~ 24 hours for D2L101.

•Faster cooldown rate is due to 1). temperature of D2L102 at the end of cooldown I is colder, 2). helium refrigerator is loaded more and recently cleaned and 3). reduction of heat load to lead pots.

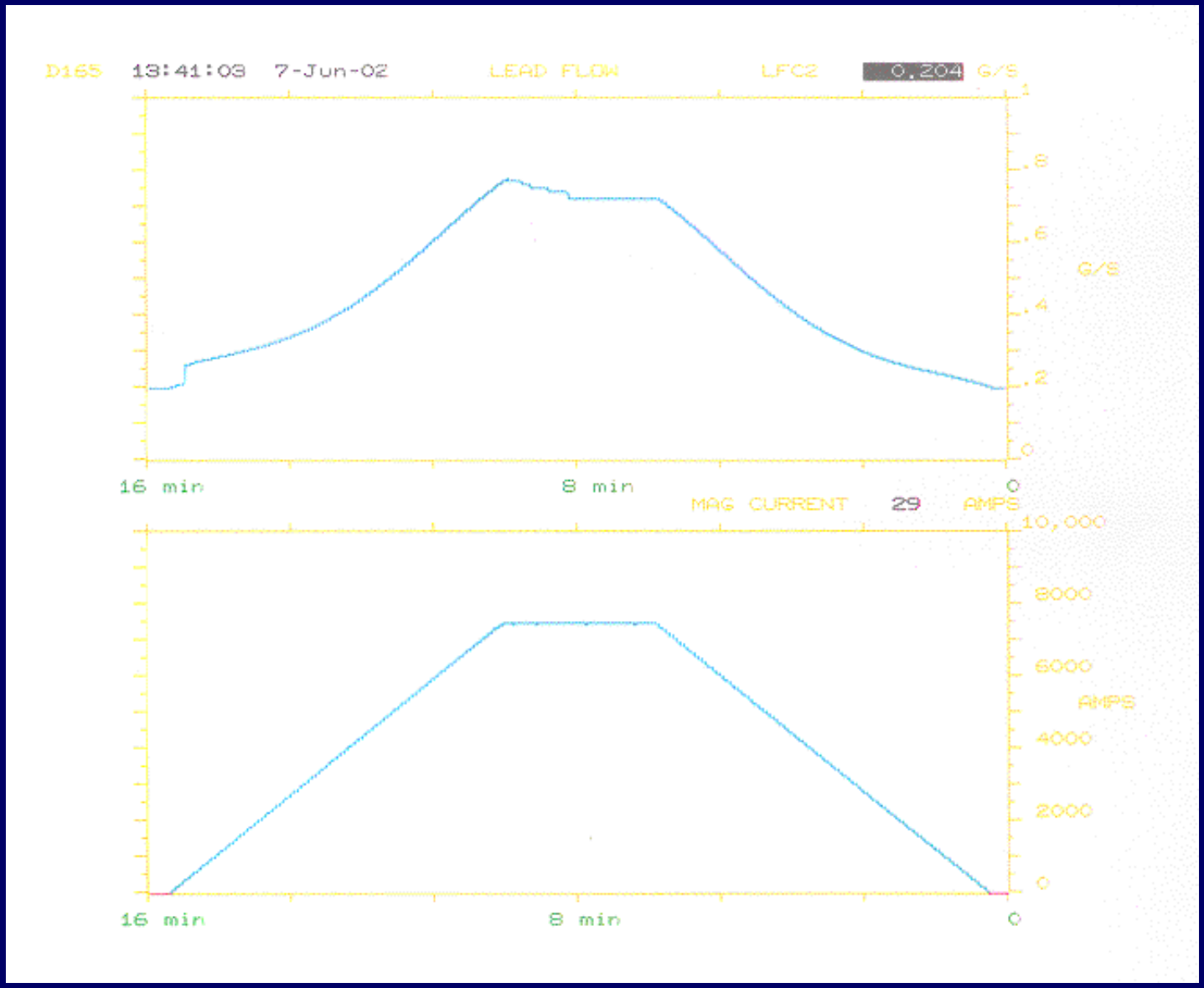
Operating Condition for D2L102 in Forced Flow Cooling



Operating Condition for D2L102 – Liquid Cool



Lead Flow and Current as a Function of Time During Powering of D2L102



Current leads

- Separate flow controllers for the 7500 A leads were not installed in time, both the (+) and (-) leads are driven by the same control
  - Since the (-) lead demands more flow than the (+) lead, flow suitable for the (-) lead will make the warm end of the (+) lead too cold
  - lead flow is carefully controlled by monitoring voltage across the (-) lead and temperature in the warm end of the (+) lead

- Lead flow used during ramping up becomes excessive after peak current is reached
  - Shall gradually reduce lead flow as soon as peak current is reached

Detailed lead flow control – for both forced flow and liquid cool

- Main leads
  - Separate flow control was not installed in time for test, the (+) and (-) are controlled using one input
  - Tare flow is set at 0.30 g/s during ramping up
  - Tare flow is gradually reduced to 0.20 g/s after peak current is reached
  - The voltage across the (-) lead is ~ 0.065 V at 7500 A.
  - The warm end of the (+) is controlled near 30 F (assisted with heater on the flag of the lead)

- Unused leads
  - 0.030 g/s of lead flow when D2 is not powered (warm end become frosty at higher flow)
  - 0.045 – 0.060 g/s during ramping

Problem and area for improvement

- 6/5 - during switching from forced flow to liquid cool,
  - Vent valve air line failed and prevent valve from opening
  - Both high pressure and low pressure relief valves
  - O-ring in the bayonet of the vent line leaked
  - Helium enters to the room
  - Cryogenic system recovers after the line warm up
- This upset causes minor helium loss and 12 hours delay but no other damage
- Insulation will be installed around the vent line to prevent liquid air from dripping onto the Feed Can

Summary

- After two training quenches, D2L102 is powered to 7500 A without quench using either forced flow cooling at ~ 4.50 K, or liquid helium at ~ 4.65 K
- The cryogenic condition between forced flow cooling and liquid cool are different but the magnetic performance for D2 is the same
- Thermal performance of Feed Can has been improved (no more quench in superconducting bus or lead)